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1	1	("6463479").PN.	USPAT	2004/05/28 10:23
2	67	(determin\$6 find\$6) near9 (home adj node\$5)	USPAT	2004/05/28 11:25
3	0	(determin\$6 find\$6 match\$5) near9 (home adj node\$5) near9 (foreign)	USPAT	2004/05/28 11:25
4	0	(determin\$6 find\$6 match\$5) near9 (home adj node\$5) with (foreign)	USPAT	2004/05/28 11:26
5	116	(determin\$6 find\$6 match\$5 identif\$9) near9 (home adj node\$5)	USPAT	2004/05/28 11:27
6	11	((determin\$6 find\$6 match\$5 identif\$9) near9 (home adj node\$5)) and (roam\$5 foreign)	USPAT	2004/05/28 11:34
8	1	broadcast\$3 near9 (identif\$6 determin\$5 match\$5 find\$5) near3 (home adj (network\$5 node\$5))	USPAT	2004/05/28 11:36
9	93	(message\$5 request\$5) near9 (identif\$6 determin\$5 match\$5 find\$5) near3 (home adj (network\$5 node\$5))	USPAT	2004/05/28 11:36
10	1	6728536.pn. and (access adj control adj server)	USPAT	2004/05/28 12:24
11	6	(aaa (authenticat\$9 near authoriz\$6 near account\$5)) near (prox\$5 gatewa\$5) near (server\$5 system\$5 device\$5)	USPAT	2004/05/28 12:25
-	27	authenticat\$6 near account\$6 near authoriz\$6	USPAT	2004/05/21 17:39
-	20	(authenticat\$6 near account\$6 near authoriz\$6) and aaa	USPAT	2004/05/20 14:27
-	2	(authenticat\$6 near account\$6 near authoriz\$6) and aaa and (service near level\$3 near agreement\$5)	USPAT	2004/05/27 12:53
-	54	((authenticat\$6 near account\$6 near authoriz\$6) aaa) and ((service near level\$3 near agreement\$5) sla)	USPAT	2004/05/20 14:38
-	10	((("6418306") or ("6393112") or ("5966431") or ("5852660") or ("6421714") or ("6286052") or ("6266782") or ("5909550") or ("5701120") or ("5642515")).PN. roam\$5 and (ip near regist\$9)	USPAT	2004/05/20 14:39
-	42	((authenticat\$6 near account\$6 near authoriz\$6) aaa) and (ip near regist\$9)	USPAT	2004/05/21 17:19
-	11	((authenticat\$6 near account\$6 near authoriz\$6) aaa radius) with (request\$6 regist\$9) with (sla (service adj level\$5 adj agreement\$6))	USPAT	2004/05/21 17:38
-	1	6466964.pn. and (home near network\$5)	USPAT	2004/05/21 17:45
-	1	6445922.pn. and regist\$9	USPAT	2004/05/21 17:47
-	1	6445922.pn. and (regist\$9 with (aaa authenticat\$5 account\$6))	USPAT	2004/05/24 16:52
-	1	6445922.pn. and ((aaa authenticat\$5 account\$6))	USPAT	2004/05/24 17:00
-	1	6445922.pn. and (('14' aaa authenticat\$5 account\$6))	USPAT	2004/05/24 17:00
-	1	6445922.pn. and (regist\$9 with (faaa haaa authenticat\$5 account\$6))	USPAT	2004/05/24 17:02
-	1	6445922.pn. and ((faaa haaa authenticat\$5 account\$6))	USPAT	2004/05/24 17:01
-	1	6466977.pn. and (roam\$5 home foreign)	USPAT	2004/05/24 17:02
-	2085	(sla (service\$3 adj level adj agree\$6)) (iwf (interworking adj function\$5))	USPAT	2004/05/24 17:24
-	2105	(sla (service\$3 adj2 level\$5 adj2 agree\$6)) (iwf (interwork\$6 adj2 function\$5))	USPAT	2004/05/24 17:24
-	1	(sla (service\$3 adj2 level\$5 adj2 agree\$6)) and (iwf (interwork\$6 adj2 function\$5))	USPAT	2004/05/24 18:09
-	1482	(sla (service\$3 adj2 level\$5 adj2 agree\$6))	USPAT	2004/05/24 18:09
-	1481	(sla (service\$3 adj level\$5 adj agree\$6))	USPAT	2004/05/24 18:10
-	268	((service\$3 adj level\$5 adj agree\$6))	USPAT	2004/05/25 13:17

-	62	((service\$3 adj level\$5 adj agree\$6)) with (improv\$5 bandwidth speed (load adj balanc\$5) rout\$5)	USPAT	2004/05/24 18:11
-	17	(sla (service\$3 adj level\$5 adj agree\$9)) with (fit\$3 assur\$5)	USPAT	2004/05/25 17:19
-	97	(sla (service\$3 adj level\$5 adj agree\$9)) with (provid\$5 near9 service\$5)	USPAT	2004/05/25 14:00
-	2	agreement adj service adj level	USPAT	2004/05/28 11:24
-	1	aaa (authenticat\$6 adj authoriz\$6 adj account\$6) adj (proxy broker\$5) adj (server\$5)	USPAT	2004/05/25 15:02
-	0	(mobile\$3 adj (device\$5 node\$5)) with (roam\$5 adj (node\$5 device\$5))	USPAT	2004/05/25 14:20
-	4	mobile\$3 with (roam\$5 adj (node\$5 device\$5))	USPAT	2004/05/25 14:28
-	1	6466977.pn. and (roam\$5 mobil\$5 cellular\$5)	USPAT	2004/05/25 14:31
-	3755	domain\$3 near9 network\$5	USPAT	2004/05/25 14:31
-	22	domain\$3 near9 (home adj network\$5)	USPAT	2004/05/25 14:37
-	21	(roam\$5 near4 service\$5 near4 provider\$5) with foreign	USPAT	2004/05/25 14:38
-	24	(roam\$5 near service\$5 near provider\$5)	USPAT	2004/05/25 14:45
-	6	aaa (authenticat\$6 adj authoriz\$6 adj account\$6) adj (proxy broker\$5)	USPAT	2004/05/25 15:03
-	11	aaa (authenticat\$6 adj authoriz\$6 adj account\$6) near4 (proxy broker\$5)	USPAT	2004/05/25 15:17
-	1	6728536.pn. and (regist\$9)	USPAT	2004/05/25 15:28
-	1	6728536.pn. and (aaa-b '120')	USPAT	2004/05/25 15:44
-	1	6728536.pn. and (respon\$6)	USPAT	2004/05/25 16:00
-	1	6445922.pn. and (reject\$5 den\$6 refus\$6 fail\$6 fault\$6)	USPAT	2004/05/25 16:12
-	37	(home adj (node\$3 terminal device\$3)) near9 (reject\$5 den\$6 refus\$6 fail\$6 fault\$6)	USPAT	2004/05/25 16:13
-	1	6728536.pn. and (agree\$6 level\$5)	USPAT	2004/05/25 17:07
-	26	(sla (service\$3 adj level\$5 adj agree\$9)) with (availability)	USPAT	2004/05/26 12:49
-	1	6728536.pn. and (broker\$5 with (network\$5 rout\$6))	USPAT	2004/05/27 13:54
-	6	((authenticat\$6 near account\$6 near authoriz\$6) aaa) adj (proxy broker\$5)	USPAT	2004/05/27 13:42
-	2	("6466977" "6728536").pn. and (key)	USPAT	2004/05/27 13:55
-	2	("6466977" "6728536").pn. and (key\$5)	USPAT	2004/05/27 13:55
-	2	("6466977" "6728536").pn. and (certificat\$6 key\$5)	USPAT	2004/05/27 14:43
-	1578	certificat\$5 near8 (key\$3 encrypt\$6)	USPAT	2004/05/27 13:58
-	649	certificat\$5 near8 (key\$3 near9 encrypt\$6)	USPAT	2004/05/27 13:58
-	0	(alternativ\$5 adj3 path\$3) near3 authenticat\$6	USPAT	2004/05/27 14:11
-	0	(alternativ\$5 near4 path\$3) near3 authenticat\$6	USPAT	2004/05/27 14:11
-	135	(path\$3) near3 authenticat\$6	USPAT	2004/05/27 14:28
-	9	avp with (attribut\$5)	USPAT	2004/05/27 14:40
-	0	6728536.pn. and (ppp l'2'tp tunnel\$5)	USPAT	2004/05/27 14:30
-	1	6728536.pn. and (ppp point l'2'tp tunnel\$5)	USPAT	2004/05/27 14:30
-	1	6728536.pn. and (ppp point\$6 l'2'tp tunnel\$5)	USPAT	2004/05/27 14:31
-	2	("6466977" "6728536").pn. and (ppp point\$6 l'2'tp tunnel\$5)	USPAT	2004/05/27 14:31
-	718	(avp (attribut\$5 adj value\$3 adj pair\$5))	USPAT	2004/05/27 14:41
-	120	((avp (attribut\$5 adj value\$3 adj pair\$5))) and (709/\$ 713/\$ 714/\$ 370/\$ 379/\$ 455/\$).ccls.	USPAT	2004/05/27 14:45
-	1	("6466977" "6728536").pn. and (virtual privat\$6 tunnel\$6)	USPAT	2004/05/27 14:43
-	108	((avp (attribut\$5 adj value\$3 adj pair\$5))) and (certificat\$6 encapsulat\$6)	USPAT	2004/05/27 14:46
-	2	("6466977" "6728536").pn. and (password\$5 user\$5 id attribut\$5)	USPAT	2004/05/27 16:18

-	2	("6466977" "6728536").pn. and (radius expir\$9 password\$5 id\$6 attribut\$5)	USPAT	2004/05/27 16:37
-	2	("6466977" "6728536").pn. and (radius expir\$9 name\$3 password\$5 id\$6 attribut\$5)	USPAT	2004/05/27 16:39
-	2	("6466977" "6728536").pn. and ((aaa adj (data information\$5)) radius expir\$9 name\$3 password\$5 id\$6 attribut\$5)	USPAT	2004/05/27 16:39
-	2	("6466977" "6728536").pn. and (aaa radius expir\$9 name\$3 password\$5 id\$6 attribut\$5)	USPAT	2004/05/27 17:03
-	2	("6466977" "6728536").pn. and (ip)	USPAT	2004/05/27 17:34
-	76	attribut\$5 near pair\$3 near value\$3	USPAT	2004/05/28 12:10
-	23	(attribut\$5 near pair\$3 near value\$3) and 709/\$.ccls.	USPAT	2004/05/27 17:14
-	0	(attribut\$5 near pair\$3 near value\$3) with (verif\$6 identif\$9 secur\$6 priva\$6)	USPAT	2004/05/27 17:16
-	9	(attribut\$5 near pair\$3 near value\$3) same (verif\$6 identif\$9 secur\$6 priva\$6)	USPAT	2004/05/27 17:32
-	146	(fault adj tolerance\$5) with (redunden\$6 plurality)	USPAT	2004/05/27 17:33
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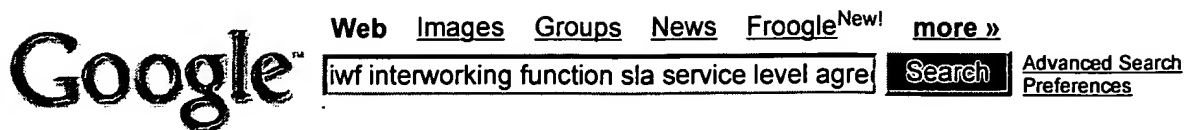
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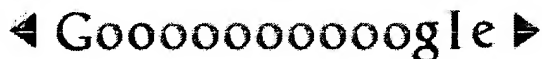
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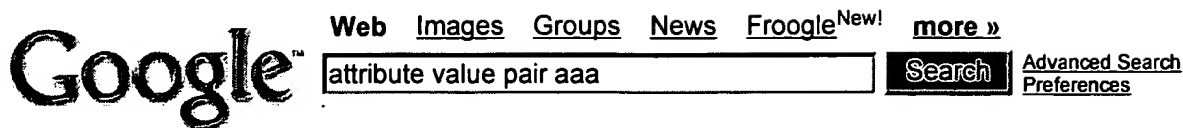


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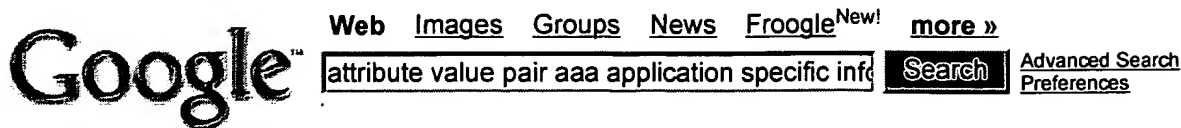
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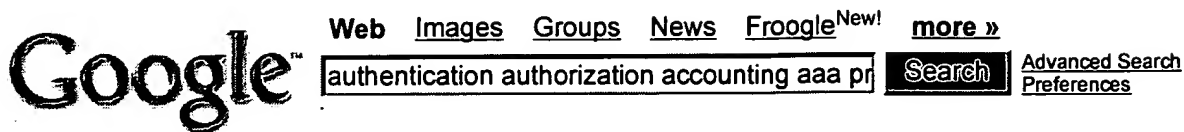
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2. Generic AAA Architecture

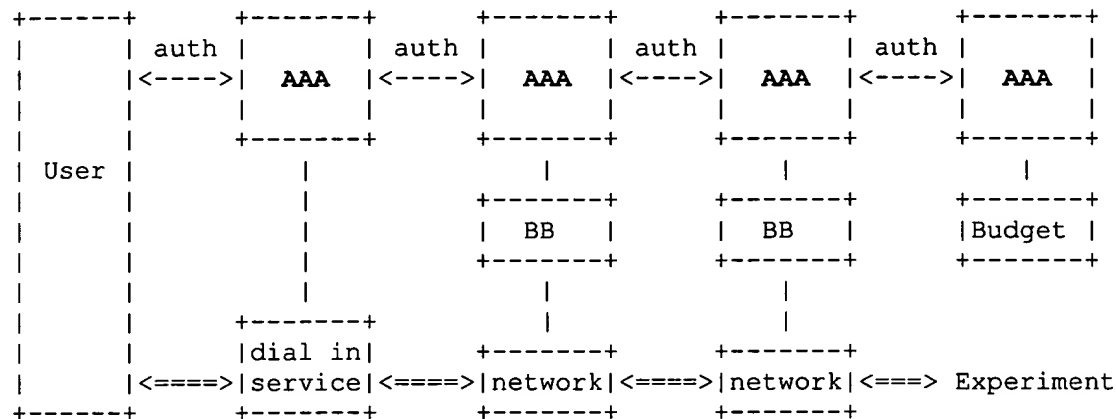
For the long term we envision a generic **AAA** server which is capable of authenticating users, handling authorization requests, and collecting accounting data. For a service provider, such a generic **AAA** server would be interfaced to an **application specific** module which manages the resource for which authorization is required. Generic **AAA** components would also be deployed in other administrative domains performing authorization functions.

2.1. Architectural Components of a Generic AAA Server

2.1.1. Authorization Rule Evaluation

The first step in the authorization process is for the user or an entity operating on the user's behalf to submit a well-formatted request to an **AAA** server. A generic **AAA** server has rules (logic and/or algebraic formulas) to inspect the request and come to an authorization decision. The first problem which arises is that **Application Specific Information** (ASI) has to be separated from the underlying logic for the authorization. Ideally the **AAA** server would have a rule based engine at this point which would know the logic rules and understand some generic **information** in the request, but it would not know anything about **application specific information** except where this **information** can be evaluated to give a boolean or numerical **value**. It should be possible to create rules that refer to data elements that were not considered when the **application** was created. For example, one could request to do a remote virtual control room experiment from home using a dialin provider. The request would only be successful if the dialin access server allows it and if there is bandwidth available (bandwidth broker) and if the experimenter has the money to pay for it (E-Commerce). Possibly the

people who specified the bandwidth broker protocol did not think of combining quality of service with a network service authorization in a single AAA request, but this generic model would allow it.



```
user <-> dialin <-> backbone with BB <-> <remote experiment>
```

Fig. 1 -- Example of a Multi Domain Multi Type of Server Request

2.1.2. Application Specific Module (ASM)

Ultimately an **AAA** server needs to interact with an **application specific** module (ASM). In a service provider, the ASM would manage resources and configure the service equipment to provide the authorized service. It might also involve itself in the authorization decision because it has the **application specific** knowledge required. A user home organization (UHO) may require ASMs as well, to perform **application specific** user authorization functions. For example, a UHO ASM might be required to access certain **application specific** databases or interpret **application specific** service level specifications.

Whatever the role of an administration relative to an authorization decision, the capabilities of the generic **AAA** server and the interface between it and the ASMs remains the same. This interface may be an **Application** Program Interface (API) or could even be a protocol based interface. In this model, however, the **application specific** module is regarded as a separate architectural component from the generic **AAA** server. As such, it must be addressable and must therefore be part of a global naming space.

2.1.3. Authorization Event Log

For auditing purposes, the generic server must have some form of database to store time-stamped events which occur in the AAA server. This database can be used to account for authorizations which were given, but it can also be used in rules. One can imagine rules in which an authorization is only given if some other event was logged in the past. With the aid of certificates, this database could support non-repudiation.

2.1.4. Policy Repository

A database containing the available services and resources about which authorization decisions can be made and the policy rules to make them is also needed. Here too, the naming space for the services and resources is important since they must be addressable from other **AAA** servers to be able to build complex authorization requests.

2.1.5. Request Forwarding

Due to the multiple administrative domain (multi-kingdom) nature of the **AAA** problem, a mechanism to forward messages between **AAA** servers is needed. The protocol by which two **AAA** servers communicate should be a peer-to-peer protocol.

2.2. Generic AAA Server Model

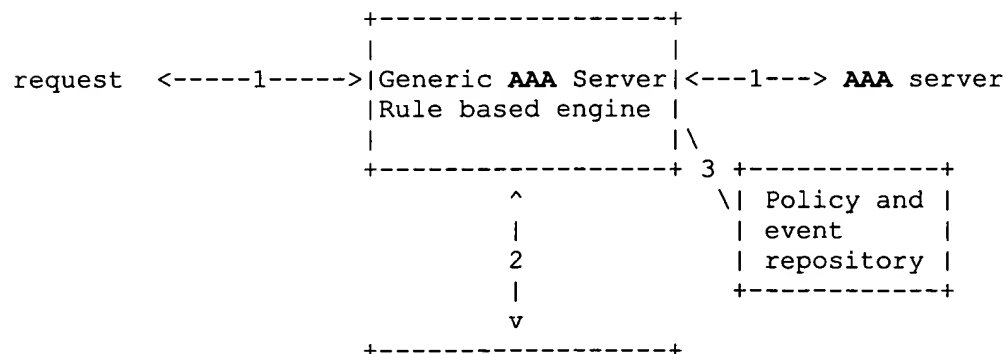
With the implementation of the above mentioned components, the **AAA** server would be able to handle **AAA** requests. It would inspect the contents of the request, determine what authorization is requested, retrieve the policy rules from the repository, perform various local functions, and then choose one of the following options to further process each of the components of the request:

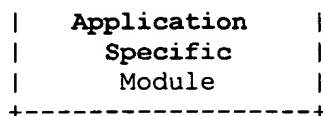
- a) Let the component be evaluated by an attached ASM.
- b) Query the authorization event log or the policy repository for the answer.
- c) Forward the component(s) to another **AAA** server for evaluation.

In the following sections we present the generic model.

2.2.1. Generic AAA Server Interactions

Figure 2 illustrates a generic **AAA** Server with connections to the various architectural components described above. In this model, the user or another **AAA** server contacts the **AAA** server to get authorization, and the **AAA** server interacts with the service. The request is sent to the **AAA** server using the future **AAA** protocol. The server interacts with the service via a second protocol which we have labeled as type "2" in the figure. We say no more of the type 2 protocol than that it must support some global naming space for the **application specific** items. The same holds for the type 3 communication used to access the repository.





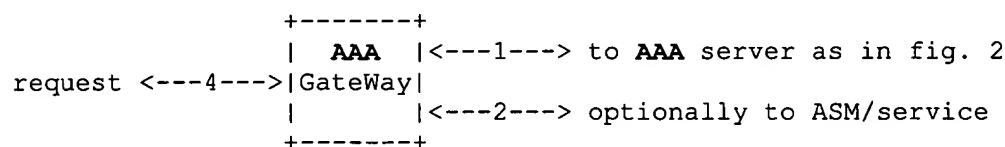
The numbers in the links denote types of communication.

Fig. 2 -- Generic AAA Server Interactions

2.2.2. Compatibility with Legacy Protocols

Because of the widespread deployment of equipment that implements legacy AAA protocols and the desire to realize the functionality of the new AAA protocol while protecting the investment in existing infrastructure, it may be useful to implement a AAA gateway function that can encapsulate legacy protocol data units within the messages of the new protocol. Use of this technique, for example, would allow Radius **attribute value** pairs to be encapsulated in **Application Specific Information** (ASI) units of the new protocol in such a way that the ASI units can be digitally signed and encrypted for end-to-end protection between a service provider's AAA server and a home AAA server communicating via a marginally trusted proxy AAA server. The service provider's NAS would communicate via Radius to the service provider's AAA server, but the AAA servers would communicate among themselves via the new AAA protocol. In this case, the AAA gateway would be a software module residing in the service provider's AAA server. Alternatively the AAA gateway could be implemented as a standalone process.

Figure 3 illustrates an AAA gateway. Communication type 4 is the legacy protocol. Communication type 1 is the future standard AAA protocol. And communication type 2 is for **application specific** communication to **Application Specific Modules** (ASMs) or Service Equipment.



The numbers in the links denote types of communication.

Fig. 3 -- AAA Gateway for Legacy AAA Protocols

2.2.3. Interaction between the ASM and the Service

In a service provider, the **Application Specific Module** (ASM) and the software providing the service itself may be tightly bound into a single "Service **Application**". In this case, the interface between them is just a software interface. But the service itself may be provided by equipment external to the ASM, for example, a router in the bandwidth broker **application**. In this case, the ASM communicates with the service via some protocol. These two possibilities are illustrated in figure 4. In both cases, we have labeled the communication between the ASM and the service as communication type 5, which of course, is service **specific**.

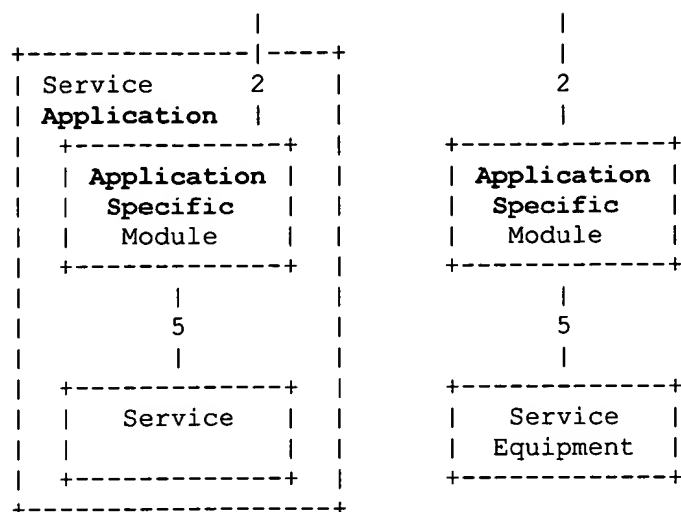
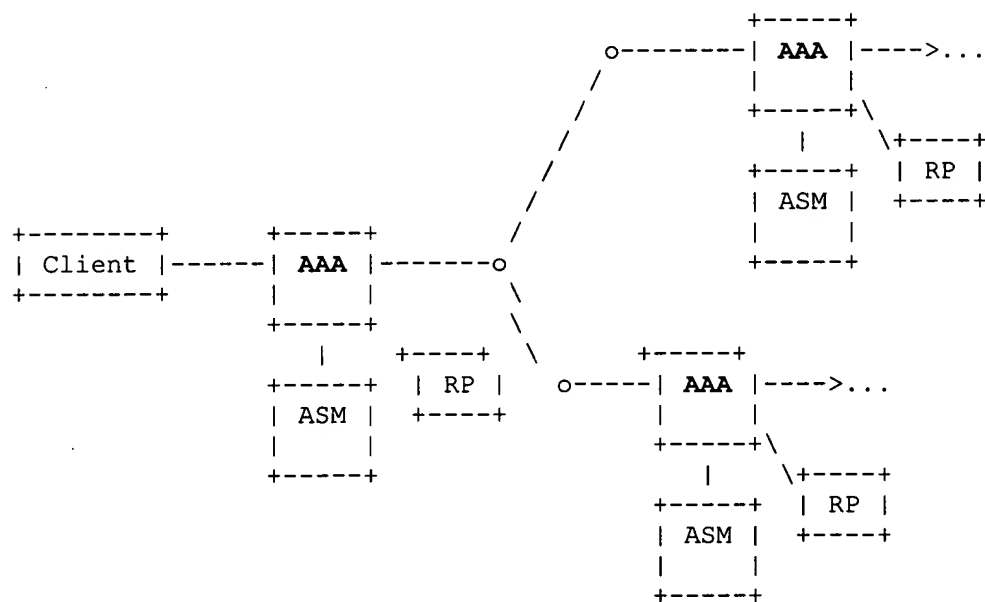


Fig. 4 -- ASM to Service Interaction (two views)

2.2.4. Multi-domain Architecture

The generic **AAA** server modules can use communication type 1 to contact each other to evaluate parts of requests. Figure 5 illustrates a network of generic **AAA** servers in different administrative domains communicating via communication type 1.



The **AAA** servers use only communication type 1 to communicate.
 ASM = **A**pplication **S**pecific **M**odule
 RP = Repository

Fig. 5 -- Multi-domain Multi-type of Service Architecture

2.3. Model Observations

Some key points of the generic architecture are:

- 1) The same generic **AAA** server can function in all three authorization models: agent, pull, and push [2].
- 2) The rule based engine knows how to evaluate logical formulas and how to parse **AAA** requests.
- 3) The Generic **AAA** server has no knowledge whatsoever about the **application specific** services so the **application specific information** it forwards is opaque to it.
- 4) Communication types 1, 2, and 3 each present their own naming space problems. Solving these problems is fundamental to forwarding **AAA** messages, locating **application specific** entities, and locating applicable rules in the rule repositories.
- 5) A standard **AAA** protocol for use in communication type 1 should be a peer-to-peer protocol without imposing client and server roles on the communicating entities.
- 6) A standard **AAA** protocol should allow **information** units for multiple different services belonging to multiple different applications in multiple different administrative domains to be combined in a single **AAA** protocol message.

2.4. Suggestions for Future Work

It is hoped that by using this generic model it will be feasible to design a **AAA** protocol that is "future proof", in a sense, because much of what we do not think about now can be encoded as **application specific information** and referenced by policy rules stored in a policy repository. From this model, some generic requirements arise that will require some further study. For example, suppose a new user is told that somewhere on a **specific AAA** server a certain authorization can be obtained. The user will need a **AAA** protocol that can:

- 1) send a query to find out which authorizations can be obtained from a **specific** server,
- 2) provide a mechanism for determining what components must be put in an **AAA** request for a **specific** authorization, and
- 3) formulate and transmit the authorization request.

Some areas where further work is particularly needed are in identifying and designing the generic components of a **AAA** protocol and in determining the basis upon which component forwarding and policy retrieval decisions are made.

In addition to these areas, there is a need to explore the management of rules in a multi-domain **AAA** environment because the development and future deployment of a generic multi-domain **AAA** infrastructure is largely dependent on its manageability. Multi-domain **AAA** environments housing many rules distributed over several **AAA** servers quickly become unmanageable if there is not some form of automated rule creation and housekeeping. Organizations that allow their services to be governed by rules, based on some form of commercial contract, require the contract to be implemented with the least possible effort. This can, for example, be achieved in a scalable

fashion if the individual user or user organization requesting a service is able to establish the service itself. This kind of interaction requires policy rule establishment between **AAA** servers belonging to multiple autonomous administrative domains.

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